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CURRENT AND FUTURE EMISSION STANDARDS FOR EXHAUST GASES AND NOISE, AND TEST PROCEDURES FOR GOODS VEHICLES

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SUMMARY

The emergence of the European Internal Market will result in an increase of the road transport of goods. Truck manufacturers and governments are keenly aware of the environmental issue posed by this increase and are reviewing the actions that should be undertaken to contain the impact of commercial vehicles on the environment in terms of exhaust emissions and noise levels.
Exhaust emissions and noise from commercial vehicle diesel engines are presently regulated by Dir. 88/77/EEC and Dir. 84/424/EEC.
A recent Commission proposal introduces a two-step plan for a further reduction in the exhaust emission limit values to be implemented in 1992 and 1996 respectively. It will apply to commercial vehicle diesel engines and is based on a test procedure which closely reflects the present conditions on European roads.
At the same time, the truck industry, the Commission and Government experts are actively pursuing the definition of possible noise levels that could still be achieved in series production vehicles. However, a further reduction in noise standards raises the problem of redefinig the measuring method before numerical recommendations can be proposed.
The introduction of these requirements will have an important impact on vehicle design and will represent a major challenge for the auto industry. It also raises the question of the quality of the diesel fuels that will be available on the market in the years to come.
Diesel fuel characteristics have an effect on both noise and exhaust emission levels. They should therefore be covered by an appropriate set of specifications.

1. INTRODUCTION

The increase in road traffic during the recent years has brought the problems related to the exhaust emissions and noise of the commercial vehicles to the attention of the public. As a consequence, the legislators are under pressure to take action in these areas.

Exhaust emissions of commercial vehicle diesel engines were originally covered by two ECE regulations dealing with the main aspects of the phenomena, i.e.:

- Regulation R-24 limiting the emission of "smoke" under full power running conditions
- Regulation R-49 limiting the emissions of unburned hydrocarbons (HC), carbon oxide (CO) and nitrogen oxides (NOx).

Technological developments in the following years made meeting more stringent requirements feasible and the truck industry started to certify new engines according to the R-49 limit values minus 20% on a voluntary basis.

The Council of Environment, on a Commission proposal, transposed both ECE regulations in the Community law with some delay, consolidating the state of the art in engine technology as far as exhaust emissions are concerned.
Table 1 summarizes the present situation.

Table 1 Present Emission Requirements for Commercial Vehicle Diesel Engines

	ECE Regulations	EEC Directive
Smoke Emission	R-24	72/306/EEC
Date of Publication	23/08/71	2/08/72
Limit Values	Abs. coef.: 2.26 - 1.065 m^{-1} in steps, as a function of the nominal flow	
Dates of Implementation	-	2/01/74
Exhaust Emissions	R-49	88/77/EEC
Date of Publication	5/04/82	3/12/87
Limit Values:		
HC g/kWh	3.5	2.4
CO g/kWh	14	11.2
NOx g/kWh	18	14.4
Dates of Implementation	-	07/88 - 10/90

Directive 88/77/EEC recognizes the need for a further step that should be undertaken at a later date and should introduce a limit value for particulate matter emissions together with more stringent limit values for the gaseous emissions.

At the same time, the requirements on engine smoke, as layed out by Dir. 72/306/EEC, are very stringent (more exacting than the corresponding requirements enforced in the US) and will still correspond to the state of the art for some years to come.

With reference to the issue of noise generated by commercial vehicles, permissible maximum levels were first introduced by Dir. 70/157/EEC.

New limit values were then established by Dir. 84/424/EEC on the basis of a comprehensive report that the truck industry issued detailing the state of the art of the available technology. A large number of existing and prototype vehicles were tested to generate the data base. These new standards (see table 2) will come fully into effect by October 90.

Table 2 Present noise level requirements
Dir. 84/424/EEC dated 3/09/84

Vehicle Category:	Noise Levels dB (A)
Busses (› 3.5 tons):	
- with an engine power ‹ 150 kW	80
- with and engine power ≧ 150 kW	83
Trucks (› 3.5 tons):	
- with an engine power ‹ 75 kW	81
- with an engine power between 75 - 150 kW	83
- with an engine power › 150 kW	84
Dates of implementation:	
Busses	1/10/88 - 1/10/89
Trucks	1/10/89 - 1/10/90

2. TEST PROCEDURE

In setting limit values for emission levels, the legislator has to define a test cycle/procedure for their measurement. The testing of the vehicle must be carried out under conditions that can be easily repeated and correlate with the average patterns of use in real life.

2.1 Test Cycle for Measuring Exhaust Emissions

At present, three test cycles for measuring exhaust emissions are widely recognized. They are:

- the European 13 Mode test cycle described by ECE (see fig.1)
- the US transient cycle developed by EPA (see fig. 2)
- the Japanese test cycle (see fig. 3)

The European 13 Mode test cycle corresponds to the combination of 3 idle modes and 10 steady state modes at 2 engine speeds (intermediate and rated speed) and five torque settings. Various studies confirm that this cycle fits well with the actual driving conditions on the European roads.

Fig. 1 Points of measurement and weighing factors of ECE R.49 13-mode cycle

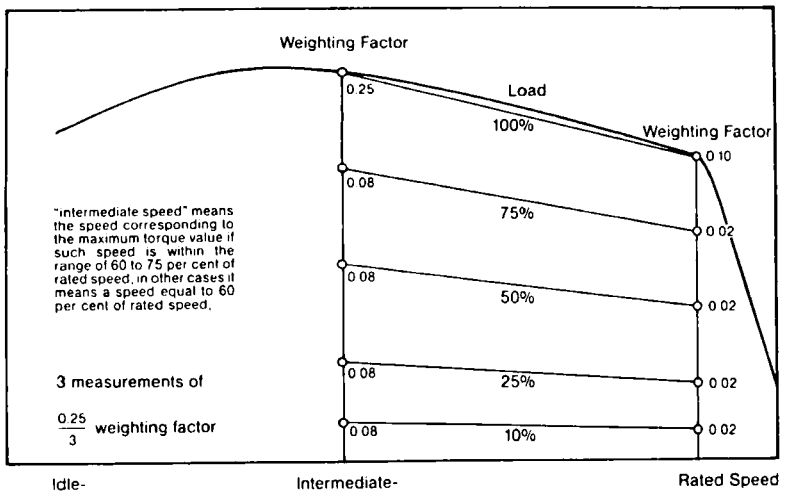


Fig. 2 US transient cycle

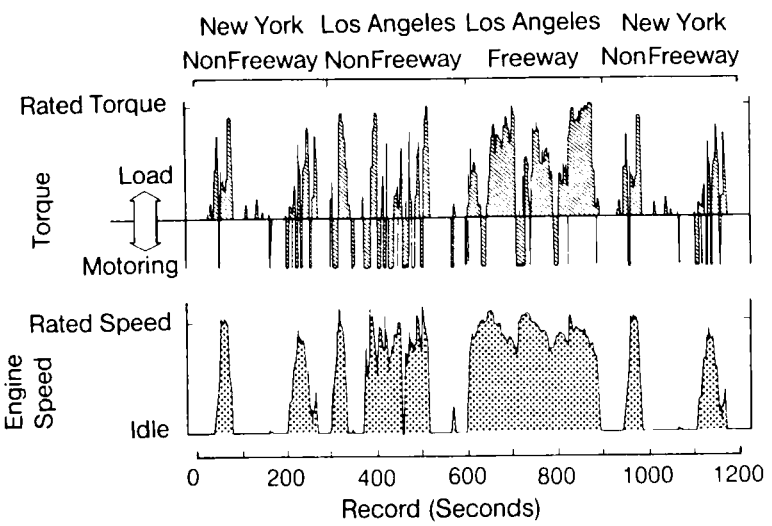
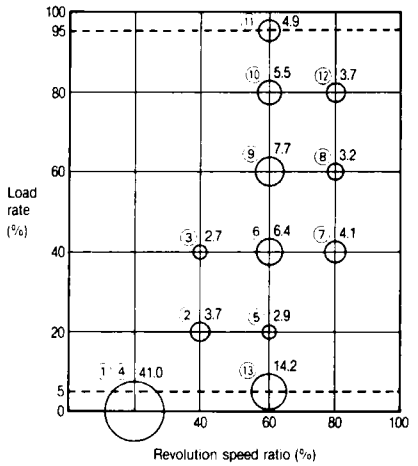


Fig. 3 Japanese Test Cycle



(Note 1) The figure on the upper right of each circle represents the coefficient percentage
(Note 2) The encircled numerals denote the driving order

Figure 4, 5a and 5b show the driving patterns of a city bus in Turin and of a truck on several Italian roads.

Fig. 4 Urban bus circuit in Turin; Engine rated speed: 2300 rpm, peak torque speed: 1400 rpm

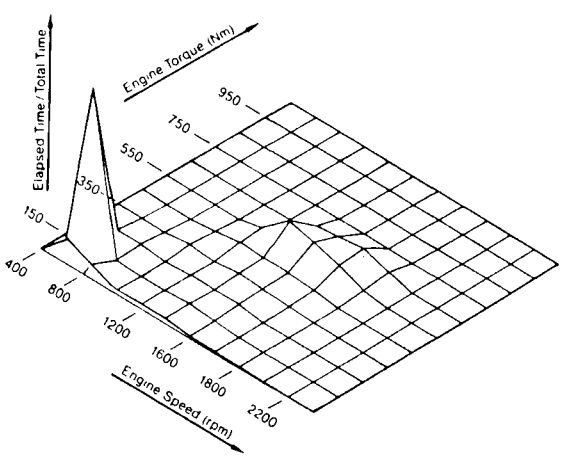


Fig. 5a Torino/Courmayeur/Torino: typical example of mixed road circuit for a gross vehicle weight equal to 38 tons; engine rated speed: 2300 rpm, peak torque speed: 1400 rpm

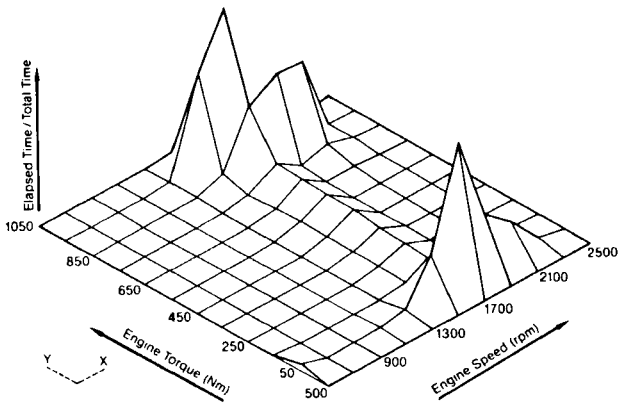
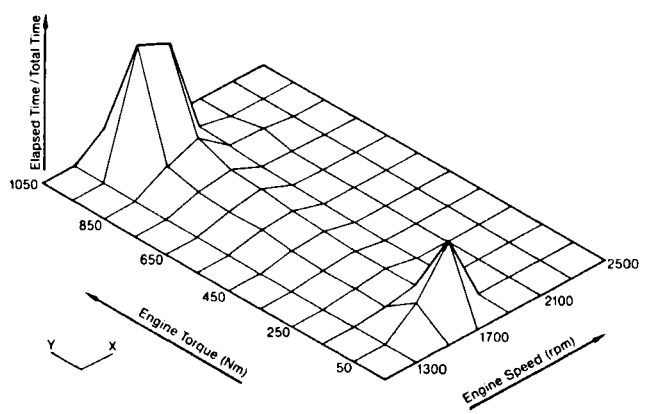


Fig. 5b Versilia Highway: typical example of highway driving conditions for a gross vehicle weight equalto 38 tons: engine rated speed: 2300 rpm, peak torque speed: 1400 rpm



The most frequent operating conditions of a commercial vehicle diesel engine are idle (city traffic) and peak torque where minimum brake specific fuel consumption is achieved. Power train of commercial vehicles are engineered to obtain minimum fuel consumption in the region close to max. torque and drivers tend to operate the vehicle in this region for evident economical considerations.

The 13 Mode test cycle was retained by Directive 88/77/EEC and has been adopted also by other European countries such as Switzerland, Sweden and Austria.

On the contrary, the US transient cycle was developed mainly around the driving patterns encountered in the cities of Los Angeles and New York. The engine operates almost exclusively close to idle and in a region characterized by 80 to 100% of the rated speed and 30 to 90% maximum load (see fig. 6). Transient modes occur at a low rate of change (see fig. 7). Deceleration modes require an engine dynamometer with monitoring capability.

Fig. 6 Time frequency of US transient cycle: performance diagram without monitoring and idle phases

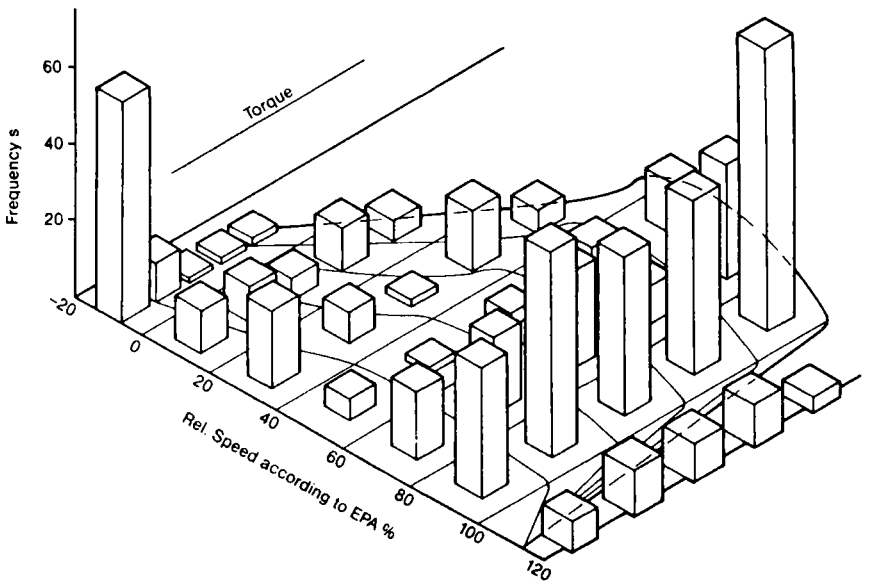
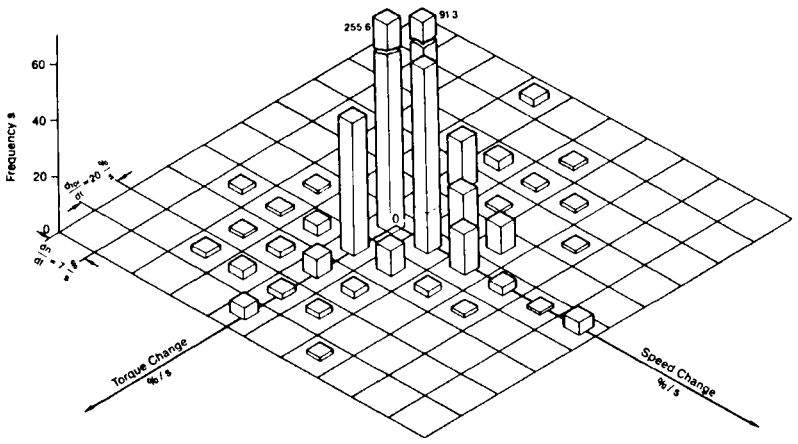


Fig. 7 Time frequency of torque and speed changes of US transient cycle without monitoring and idle phase



The main feature of this cycle is the measuring of emission levels during transient conditions which are considered important from the point of view of the formation of pollutants. However, it has been often criticized on the basis of the following considerations:

- it is questionable whether the test conditions truly reflect the most common driving patterns in the rest of the United States
- it requires the use of very sophisticated equipment in terms of the engine dynamometer and computer controlled system (an engine cell for US certifications is 6 times more expensive than the one required by the European or Japanese legislation)
- the response of the injection system to changes of the engine running conditions is almost instantaneous. Thus diesel engine transient operations, that do not occur in an extremely short time, can be well approximated by sequential steady state running modes
- under motoring conditions (decelerations) the governor of the injection pump cuts off the fuel delivery and no pollutants are emitted.

There is no apparent reason for the European legislator to follow the approach adopted by EPA and introduce the US transient cycle, in its present definition, in Europe. The Japanese government apparently shared this opinion when it defined a test cycle based on a sequence of steady state modes.

2.2 Test procedure to measure the engine smoke level

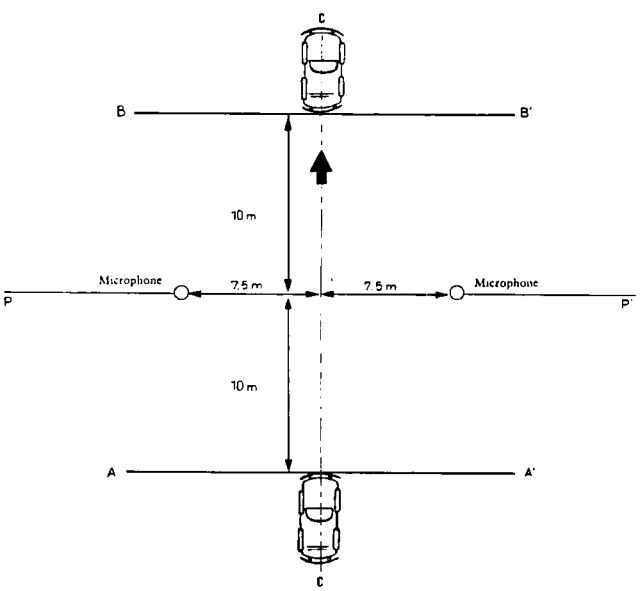
The smoke level of a diesel engine is determined using an opacimeter, i.e. an instrument capable of measuring the absorption coefficient of the exhaust gas stream when it is crossed by a light beam. These measurements are carried out under steady state full load conditions or under free acceleration. Tests under free acceleration can be used to verify the conformity of a vehicle with the legislative requirements.

2.3 Test procedure to measure the vehicle noise level

The present pass-by test with full acceleration is based on the ISO R.362 recommendation.
With reference to fig. 8, the procedure can be summarized as follows:

i) the vehicle approaches the line AA' at a steady state speed and in a fixed gear
ii) the vehicle speed is either 50 km/h or corresponds to 3/4 of the engine rated speed, whichever value is lower
iii) when crossing line AA', the vehicle is accelerated at W.O.T. and the throttle is maintained in the full-open position until line BB' is crossed.

Fig. 8 Test for measuring vehicles noise level



Care is suggested in selecting an area with low background noise level; no defined specifications are listed for the pavement surface and/or tyre type (smooth surfaces and quite tyres are recommended).
The major noise sources at the time the test was developed were the engine, the transmission, the air intake/exhaust systems and the radiator/fan systems.

3. EVOLUTION OF THE LEGISLATIVE REQUIREMENTS

Road transport is today the most efficient way to move goods throughout Europe. Consequently, with the completion of the internal market in '92, the road traffic is expected to increase considerably. Actions are deemed necessary by public opinion in order to assure that this evolution will not take place to the detriment of the environment.
The Commission has already layed out the plan for a further tightening of the exhaust emission standards while new, more stringent requirements for vehicle noise levels are being discussed by the national experts within the ERGA-Noise group.

3.1 Future Exhaust Emission Standards

The Commission has recently disclosed its proposal for the future emission standards. Table 3 outlines this proposal and compares the limit values with those that will be implemented in the near future in other European countries. For reference, we also include the limit values that have been proposed to the Commission by the industry.

Table 3 Commercial Vehicle Diesel Engines Emission Standards (in g/kWh)

	Commission Proposal		Switzerland	Sweden	CCMC Proposal	
	Step I	Step II			Step I	Step II
CO	4.5	4.0	4.9	4.9	5.0	3.8
HC	1.1	1.1	1.23	1.2	1.25	1.0
NOx	8.0	7.0	9.0	9.0	9.0	7.0
Particulates	⩽ 85 kW 0.63 > 85 kW 0.36	0.3/0.15*	0.7	0.4	> 150 kW 0.4 ⩽ 150 kW 0.7	> 150 kW 0.25 ⩽ 150 kW 0.50
Dates of Implementation	NT: 1.7.92 ANV: 1.1.93	NT: 1.10.96 ANV: 1.10.97		model year 1994	NT: end'92 ANV: in steps	NT: late'96 ANV: in steps
Test Fuel	current	low Sulphur* low Arom.			low Sulphur	low Sulphur low Arom.

* P.M. limit values and test fuel specifications to be defined by the Council, on a Commission proposal, before the end of '94.

NT: New types
ANV: All new vehicles

The CCMC regrets that the Commission has decided not to accept its proposal.
The truck industry has already proven their concern about the environment in the recent past. The limit values brought forward are very progressive and would have ensured the uniformity of the emission requirements in Europe. On the other hand, the Commission proposal overlooks the following fundamental issues:

i) **implementation dates:** truck manufacturers produce a large number of engine types to meet their customers' demand. The process to obtain the type approval for all of them has been estimated in approximately 2.5 years and involves considerable efforts from both national authorities and truck manufacturers.
Even within the hypothesis that the Commission proposal can be finalized in a Directive by mid '91, the time interval provided for the implementation of the new requirements to the full production will not be sufficient (mid '91 to January '93).

ii) **lead time for engineering and production planning:** the emission limit values being proposed for '92 require an important evolution of the present HDD engine population. The definition of the technical solutions and the planning of their introduction in full production require a sufficient lead time (3-5 years).
The '92 dates of implementation of the new requirements for new types is feasible only as a consequence of development efforts undertaken by the industry on a voluntary basis.

iii) **exhaust emission levels:** while awaiting guidelines from the Commission, the development of low emitting engines was started with the goal of meeting the limit values proposed by CCMC. Any deviation from these figures will add to the engineering efforts currently underway and raise the need for longer lead times.

iv) **diesel fuel quality:** the issue posed by the diesel fuels quality cannot and should not be overlooked, especially in view of the long term goals proposed by the Commission/ CCMC.
A decision in '94 will be too late to be effective.

It is also premature to discuss particulate limit values below 0.25 g/kWh at this time. They will require the use of an exhaust gas after treatment system. Two types of such systems are presently being evaluated:

a) particulate filters - field tests on city busses are underway in several European locations. The feasibility of these systems in urban driving conditions has been demonstrated. However, further optimization of the system lay out is still needed in view of their widespread use on urban vehicles.
b) catalytic converters: important reduction of the soluble particulate fractions and gaseous unburnt components such as CO and HC can be achieved. It is however questionable whether they are sufficient to reach such low P.M. emission levels.

The widespread use of the above systems is also hindered by the sulphur content of today's diesel fuels (0.3% in most of the EEC Member States; 0.2% in Germany).
The installation of particulate filters will also require the reviewing of the test procedures for diesel engine type approval with specific reference to the engine power and smoke (Dir. 72/306/EEC) measurements.

3.2 Future Noise Standards

The further tightening of the permissible levels for vehicle noise is being debated by the ERGA-Noise group of the Commission. No final recommendations have been reached yet at the writing of this report.
One important issue raised during the discussion has been the need to improve the test procedure for measuring the vehicle noise.
As vehicle noise levels were reduced in the past years, the test surface and the interaction between pavement and tyres have acquired increased importance in determining the test results.
There is the need for a more precise definition of the test conditions before reviewing the feasibility of meeting noise standards more stringent than the present levels.
Other issues that should be carefully evaluated are the following:

- truck manufacturers, especially those manufacturing heavy vehicles, market a large number of different models which exceed 15000 covering the EEC sales of around 300.000 units per year
- model life, and more particularly major components life cycles, are extremely long
- technical solutions to reduce the noise levels often involve major vehicle redesign and can be introduced only at the time of a model change
- as discussed in the above chapter, significant changes in exhaust emission requirements are planned in '92 and in '96. Their impact on the vehicle noise levels should be fully evaluated in oder to confirm the feasibility of more stringent noise standards
- diesel fuel quality plays a role not only concerning engine emissions but also engine noise levels.

The ERGA-Noise group has identified urban noise as a key element in the discussion.
A possible compromise solution between the political need to see progress in this area and the industrial reality could be to require certain categories of vehicles to be produced or available in "low noise" version by certain dates.

4. RECOMMENDATIONS

The European truck manufacturers are concerned about the environment and are willing to develop and market environmental friendly vehicles in terms of exhaust emissions and noise levels. The legislator must guide the industry efforts towards this goal by defining requirements and their corresponding dates of implementation. This task should be carried out taking into proper account certain unavoidable constraints posed by the

availability of technical solutions, the need of sufficient lead time for their development and the planning of their introduction in full production, and the related social costs (vehicle prices and fuel consumption levels). Achieving harmonization of the legisltative requirements throughout Europe is another important goal.
Therefore, CCMC would like to put forward the following recommendations:

- the CCMC proposal concerning future emission standards for commercial vehicle diesel engines should be adopted without any amendment with specific reference to the limit values and dates of implementation. This proposal is based on the following considerations:

  o the development work that the industry has already carried out on a voluntary basis
  o the lead time necessary for the system definition and **required by the procedure for obtaining the type approval certificate**
  o the need to reach an harmonization of the emission requirements within Europe

- with regard to the setting of future noise standards, the quantification of any limit value must be based on a realistic assessment of what is achievable both in terms of technical feasibility and timing

- the industry cannot envisage a generally applied 80 dB (A) limit on heavy trucks until at least the end of the century

- limit values of 2-3 dB (A) lower than the present requirements for urban busses and urban delivery vehicles by '96 may be an acceptable compromise

- the oil industry should be asked to join the truck manufacturer efforts in making available environmental friendly products that meet the public expectation.

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